PATENT SPECIFICATION

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DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Improvements in or relating to Axial-Flow Compressors.

We, POWER JETS (RESEARCH AND DEVELOPMENT) LIMITED, of 25 Green Street, London, W.1, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to axial flow compressors having rows of stator and rotor blades in which the blades of at least one of the rows are supported by root fixings and carry blade tip shrouding. As herein used, the expression "stator blades" excludes inlet guide vanes. It is known that in such a row of rotor or stator blades the fluid flow is decelerated and accordingly there is a tendency for the blades to stall and thus reduce the efficiency of the compressor. The present invention aims to counteract such loss of efficiency in a compressor.

According to the present invention, an axial flow compressor having a row of rotor or stator blades supported by root fixings and carrying blade tip shrouding has means located in the region of the shrouding which afford one or more paths for the flow of working fluid from the channel on one side of a blade to the channel on the opposite side thereof. Normally, a wall adjacent to or forming part of the blade root extends laterally of the blade at its root end and similar means may in addition be located in the region of such wall to provide one or more paths for the flow of working fluid between the said channels.

The invention derives from the proposition that a beneficial effect on the performance of blades having at one end a tip clearance from adjacent structure is attributable to turbulence in the fluid near the blade tips induced by a mixing flow across the blade tips between adjacent blade channels. The effect is diminished as the tip clearance is reduced. The invention is intended to provide a similar effect by promoting turbulence in the region of the shrouded end of a blade, and possibly also in the region of the blade root, where it is supposed normally to be largely inhibited.

The invention may be readily understood from the following description with reference to the accompanying drawings of various constructional embodiments thereof in a multi-stage axial flow compressor. In the drawings:—

Fig. 1 is part of a longitudinal section of the compressor taken along the axis thereof and showing successive blade stages.

Fig. 2 is a section through the blade stages of the compressor taken in the direction of the arrows II—II in Fig. 1.

Fig. 3 is a section through the blade stages of the compressor taken in the direction of the arrows III—III in Fig. 1.

The compressor has a stator casing 1 and rotor 2 which may be constructed in any conventional manner. The stator casing carries a row of inlet guide vanes 3 and successive rows of stator blades 5, 7, 9, 11 while the rotor carries successive rows of rotor blades 4, 6, 8, 10, 12. The blades of each row define a plurality of flow channels for the working fluid.

The rotor blades 4 each have a root 13 with projections 14 entered in a peripherally extending re-entrant groove 15 in the rotor. At the radially outer ends of the blades 4 is a shroud 16 extending circumferentially of the blade row. The shroud may be circumferentially continuous or interrupted at one or more points, each part of the shroud

being conveniently attached to a number of blades. The end face of each blade 4 has a radial projection 17 passing through the shroud and deformed to secure the latter against the end face of the blade. The shroud lies in a channel 18 in the stator casing and bounds the fluid flow path through the compressor. In accordance with the invention the end face of the blade 4 has recesses 19 so that the end of the blade is of castellated or similar form, the recesses passing across the thickness of the blade profile. Thus the working fluid can freely flow from one to the other side of the blade 4.

Each stator blade 5 has a root spigot 20 entered in a complementary recess 21 in the stator casing and attached thereto by the threaded root extension 22 and nut 23. In the region adjacent to the spigot the blade overlaps the stator casing with a small gap 24, through which gap working fluid can pass across the blade profile. The radially inner ends of the stator blades have a shroud 25 corresponding to the shroud 16 of the rotor blades 4. Similarly the shroud 25 also lies in a channel 26 in the rotor 2, and is attached to each blade 5 through a projection 17. Immediately adjacent to the shroud 25, the blade 5 is recessed to provide gaps 27 on each side of the projection 17.

The rotor blades 6 have roots 13 providing a boundary wall to the working fluid flow, which wall extends laterally on each side of a blade, and shrouds 16 corresponding to those of blades 4. Similarly the shroud lies as before in a channel 18. Holes pass through each blade 6 near the shroud and may be circular as at 28 or rectangular as at 29, and may extend to the blade edge as at 30. Similar holes 31, 32 are provided near the root 13, being radially orientated as shown to avoid any excessive weakening of the blades under centrifugal loads.

The stator blades 7 each have a root 33 with projections 34 entered in a complementary peripheral groove 35 in the stator casing. The blades have a shroud 25 corresponding to that of blades 5 lying similarly in a channel 26 in the rotor. In this case however the shroud has axially spaced dimples 36 which are slightly elongated in the circumferential direction. The dimples are positioned to extend across the blade section and define recesses to allow working fluid to flow freely across the end of the blade.

The rotor blades 8 have roots 13 and a shroud 16 corresponding generally to those of blades 4 and 6. However, the shroud has a multiplicity of circular dimples 37 extending axially and circumferentially at least in the region of abutment with the blades. The end face of each blade 8 bears on some of the dimples so that working fluid can pass across the end of the blade through the recesses formed between the dimples. Each root 13 has a blind hole 38 extending from a side face thereof obliquely to the blade profile, and branch holes 39, 40 on opposite sides of the blade ~~profile. Thus~~ working fluid can pass through these holes across the blade profile. When the blade root is positioned in its groove the open end of the blind hole 38 is closed by the side of the groove.

The stator blades 9 each have a root 33 similar to that of the blades 7 and a shroud 25 generally similar to that of blades 5 with an associated channel 26 in the rotor. In this case circular holes 41, 42 pass radially through the shroud which are positioned on opposite sides of the adjacent end profile of the blade. Accordingly working fluid can pass freely through the holes and, by way of the channel 26, across the end profile of the blade.

In the rotor blades 10 the root 13 and shroud 16 correspond to those of the blades 4. Rectangular apertures 43, 44 pass radially, through the shroud and are positioned to perform a similar function to the holes 41, 42 of the blades 9.

In the stator blades 11 the root 33 and shroud 25 correspond to those of the blades 9. Elongated slots 45, 46 are provided extending from respectively the inlet and outlet edges of the shroud and passing radially therethrough. The slots are positioned to perform a similar function to the holes 41, 42 in the blades 9.

The rotor blades 12 each have a root 13 corresponding generally to that of the blades 4 but the roots abut circumferentially on surfaces 47 inclined to the rotor axis. Each surface 47 has radial notches 48, 49 at axially spaced regions. The notches on adjacent roots co-operate to form holes extending radially into a cavity 50 at the bottom of the groove retaining the roots. The blades 12 each have a shroud member 51 which abuts with the corresponding members of adjacent blades at surfaces 52 inclined to the rotor axis. The surfaces 52 have axially spaced radial notches 53, 54 communicating with the channel 26 in which the shroud members lie. The surfaces 47 and 52 are so inclined and the notches therein are so positioned that in each case an effect is obtained similar to that of, for example, the holes 41, 42 of the blades 9.

The constructions applied to the shrouds 16 and 25 of the blades 4, 5, 6, 7 and 8 need not affect the sealing function of the shroud since the edges thereof may cooperate with the sides of the associated channel to form a rotating seal. Moreover none of the constructions described, except perhaps that relating to the shroud 25 of blades 11, need significantly reduce the

strengthening effect of the shroud on the blades.

Although the embodiments have been described for convenience as applied to alternate rotor and stator blades it will be understood that they can in general be applied to respectively stator and rotor blades. For example the embodiments described in relation to a rotor blade and its shroud 16 may be applied equally in relation to a stator blade and its shroud 25. Similarly embodiments described in relation to a stator blade and its shroud 25 can be applied equally in relation to a rotor blade and its shroud 16. The embodiments described in relation to the ends of the rotor blades 6, 8 and 12 adjacent to their roots 13 may be applied to the corresponding ends of the other rotor blades or in relation to the ends of the stator blades 7, 9 and 11 adjacent to their roots 33. Also the embodiment described in relation to the shroud members 51 of the rotor blades 12 may be applied to a corresponding shroud member on a stator blade.

It will be apparent also that some of the embodiments described may be applied in combination to a single blade. In particular any of the embodiments described in relation to the shrouded ends of blades 4, 5, 6 and 7 may be combined in a single blade with one of the embodiments described in relation to the shrouded ends of blades 9, 10 and 11.

WHAT WE CLAIM IS:—

1. An axial flow compressor having a row of rotor or stator blades supported by root fixings and carrying blade tip shrouding and having means located in the region of the shrouding which afford one or more paths for the flow of working fluid from the channel on one side of a blade to the channel on the opposite side thereof.

2. A compressor according to Claim 1 having a wall extending laterally of the blade at its root end and in addition to said means in the region of the shroud, means located in the region of said wall which afford one or more paths for the flow of working fluid from the channel on one side of the blade to the channel on the opposite side thereof.

3. A compressor according to Claim 1 or Claim 2 wherein said means or each said means include at least one recess in the profiled part of the blade, the recess extending across the thickness of the blade profile.

4. A compressor according to Claim 1 or Claim 2 wherein said means or each said means include at least one aperture in the profiled part of the blade, the aperture extending through the thickness of the blade profile.

5. A compressor according to any preceding claim wherein the face of the shrouding adjacent the profiled part of the blade is locally recessed across the thickness of the blade profile to afford at least one of said flow paths.

6. A compressor according to any preceding claim wherein said means in the region of the shrouding include apertures extending through the shrouding on opposite sides of the junction of the shrouding with the blade, the apertures communicating with a cavity bounded by the shrouding.

7. A compressor according to Claim 2 wherein said means in the region of the said wall include apertures extending partly through the root on opposite sides of its junction with the blade, the apertures communicating with a cavity in the root.

8. An axial flow compressor having tip shrouded rotor or stator blades with one or more flow paths in the region of the shrouding between working fluid channels on opposite sides of a blade substantially as in any one of the embodiments described herein with reference to the accompanying drawings.

9. A compressor according to Claim 8 having a wall extending laterally of said blade at its root end wherein said blade has in addition one or more flow paths in the region of the said wall substantially as in any one of the embodiments described herein with reference to the accompanying drawings.

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Agent for the Applicants.

PROVISIONAL SPECIFICATION.

Improvements in or relating to Compressors, Turbines and Similarly Bladed Rotary Fluid Flow Machines.

We, POWER JETS (RESEARCH AND DEVELOPMENT) LIMITED, of 25 Green Street, London, W.1, a British Company, do hereby declare this invention to be described in the following statement:—

The invention relates to compressors, turbines and similarly bladed rotary fluid flow machines having a row or rows of blading in which the blades extend transversely to the flow path of the working fluid. The blades

of a row are enveloped at one or both ends by integral shrouding to which the blades are connected and which forms a bounding wall for the fluid in the region of the blade row. Such integral shrouding may be constituted for example by rotor or stator structure to which the blades are attached or by root portions of the blades attached thereto or by a platform circumferentially of the blade row at the ends of or at an intermediate point on the blades.

The invention consists in that the flow path of fluid passing through blades connected by integral shrouding is provided in the region of the shrouding with means for disrupting or disturbing the flow of fluid adjacent to the shrouding. Such means may consist of apertures or recesses in the blades adjacent to the integral shroud or in the shroud itself, the apertures or recesses being spaced or extending across the thickness of the section of a blade. A communication is thereby afforded between the fluid traversing adjacent blade channels and a cross flow of fluid is promoted between the channels tending to disrupt or disturb the through flow. Alternative or additional means for disrupting the flow may consist of projections on or a discontinuity in the wall of the flow path in the region of the integral shrouds. Thus the projections may extend into the path from the integral shroud or from the blade parts adjacent to the shroud or from structure immediately upstream of the shroud, or any combination of such projections may be provided. Similarly a circumferential recess or series of recesses may be formed in the surface of the shroud or the structure upstream thereof.

The invention derives from the proposition that a beneficial effect on the performance of blades having at one end a tip clearance from adjacent structure is attributable to a turbulence in the fluid near the blade tips induced by a mixing flow across the blade tips between adjacent blade channels. The effect is diminished as the tip clearance is reduced. The invention is intended to provide a similar effect by promoting turbulence in the region of an integral blade shroud where it is supposed normally to be largely inhibited.

In a constructional embodiment of the invention in an axial flow turbine or compressor a row of blades each extending radially outwardly from a rotor to which they are attached have at their outer ends an integral shroud extending peripherally of the blade tips. The shroud may be circumferentially continuous or interrupted at one or more points, each part of the shroud being attached to a number of blades. The shroud is in the form of a sheet extending axially across the ends of the blades to bound the fluid path, the end face of each blade having one or more radial projections which pass through the shroud and are deformed to secure the shroud against the end face. In accordance with the invention the end face of each blade is recessed or notched at one or both sides of a radial projection, so that the end of the blade is of castellated or similar form. The recesses pass across the blade profile in the direction of the thickness of the profile and are shallow compared with the length of the blade. The recesses may extend from one or both edges of the blade or may at some intermediate point of the chord of the blade. Alternatively or additionally one or more (for example circular) holes may be provided passing through the thickness of each blade near to the end face of the blade. As another alternative or addition, the radially inner face of the shroud may be recessed or dimpled, the recesses extending in the circumferential sense across the blade tips in the direction of the thickness of the tip profile. One or more such recesses may be provided at each blade. The shroud may also be provided with holes passing through it in the radial direction on each side of the blade, the holes being spaced in the direction of the blade thickness and perhaps inclined in the circumferential sense. Such holes may be grouped in two or more circumferential series spaced in the axial direction. In each alternative construction there is accordingly provision for fluid to pass between the blade channels in the region of the shroud and only in the last alternative is the sealing effect of the shroud impaired since in the other constructions the upstream and downstream edges of the shroud may co-operate with adjacent stator structure to form a fluid seal. Nor need any of the above constructions significantly reduce the strengthening effect of the shroud on the blades.

In the aforementioned constructional forms the apertures or recesses will generally be spaced or extend across the blade tips in a circumferential direction, but where the blade section at the tip is considerably inclined to the axis of the machine the direction may be substantially axial.

In other constructional forms supplementary or alternative to those described above, the inner face of the shroud may be provided between adjacent pairs of blades with a plurality of projections spaced both axially and circumferentially, the radial height of the projections being small in relation to the length of the blades. Moreover the projections may be extended across the end of the blades so that they abut on the end face of each blade, the gaps between the projections then affording a communicating fluid path between opposite sides of the blade. Similar projections may be provided on the sides of each blade adjacent the shroud and

spaced both lengthwise and chordwise of the blade. The upstream end of the shroud or stator structure upstream of the shroud and forming with the latter a continuous flow path may be provided with similar inwardly extending projections spaced axially and circumferentially. The projections may conveniently be of cylindrical, conical or pyramidal form.

In further constructional forms which are applied alone or in combination with those forms described in the foregoing, a peripherally continuous recess of, for example, rectangular shape is provided in the inner face of the shroud in the region of the upstream edges of the blades of the row, or somewhat upstream thereof, or in the wall structure upstream of the shroud. Further a circumferential series of holes may be provided towards the trailing edges of the blades. The holes may extend radially outward from the inner face of the shroud and be in communication with a corresponding series of holes in the walls of the recess. Such communication may be by way of a space formed outwardly of the shroud or by passage extending in the axial direction through the shroud. Thus a local circulating flow between the first series of holes and the recess is promoted.

In an axial flow turbine or compressor rotor similar to that described but wherein the tip shroud for a blade row is made up of successive platforms one of which is formed on each blade, any of the foregoing constructional forms may be used except those in which the end face of the blade or the inner face of the shroud is recessed. Additionally or alternatively the circumferentially facing ends of the platform which are normally in abutment or other engagement may be recessed to provide radial channels from the inner to the outer face of the shroud. On the other hand the platforms may have holes extending from said ends and intersecting radial holes extending from the inner face of the platform on each side of the blade.

The radially inner ends of the rotor blades in either of the turbines described above may have root portions entered in and engaging a re-entrant recess extending peripherally of the rotor. Spacing members may be inserted in the groove between successive blades having on their radially outer faces axially and circumferentially spaced projections. The rotor periphery immediately upstream of the groove may instead or in addition have axially and circumferentially spaced projections. The blade parts immediately outward of the roots may have circumferentially extending holes passing from one to the other side of the blade. Two or more such holes may be aligned radially. Alternatively the width of the blade roots and their retaining recess may be reduced compared with the blade chord so that the blade immediately outward of the root overhangs the adjacent structure with a preferably slight clearance at one or both blade edges.

In addition or alternatively the rotor periphery immediately upstream of the blade retaining recess may have a circumferential recess or series of recesses interrupting the continuity of the rotor periphery in the axial direction.

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1 SHEET

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.

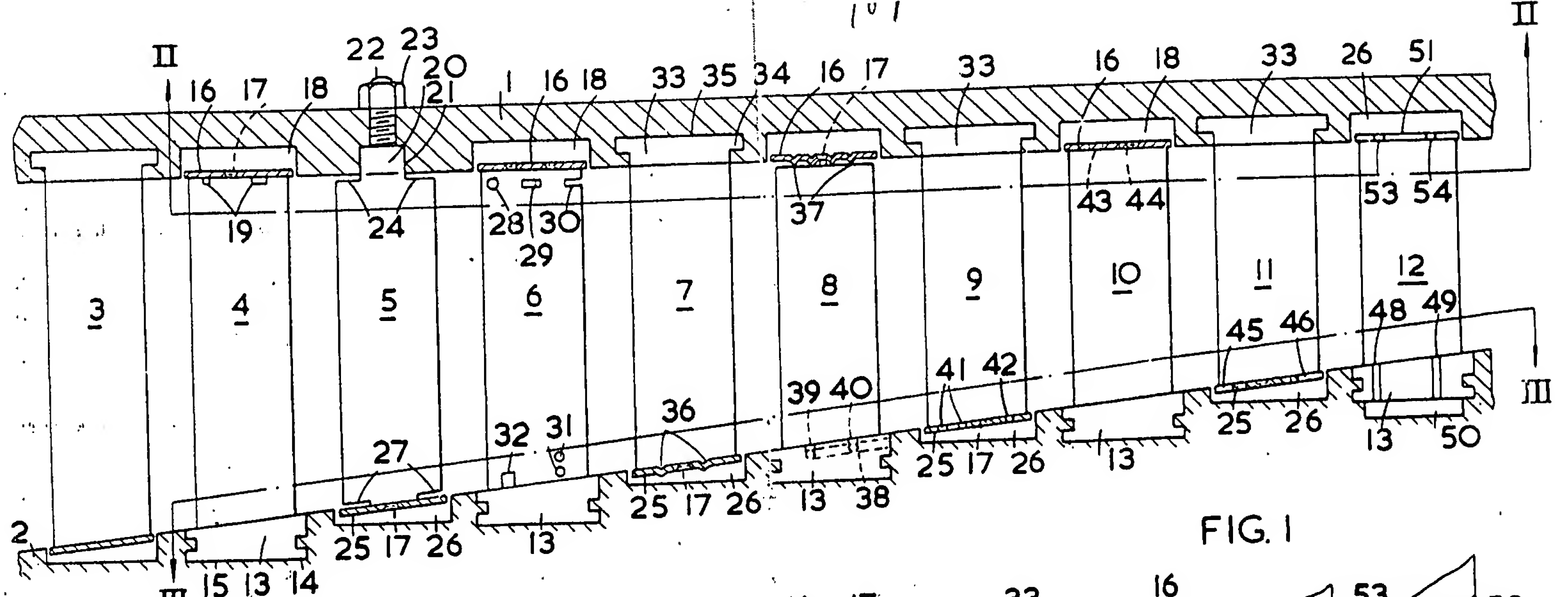

FIG. 1

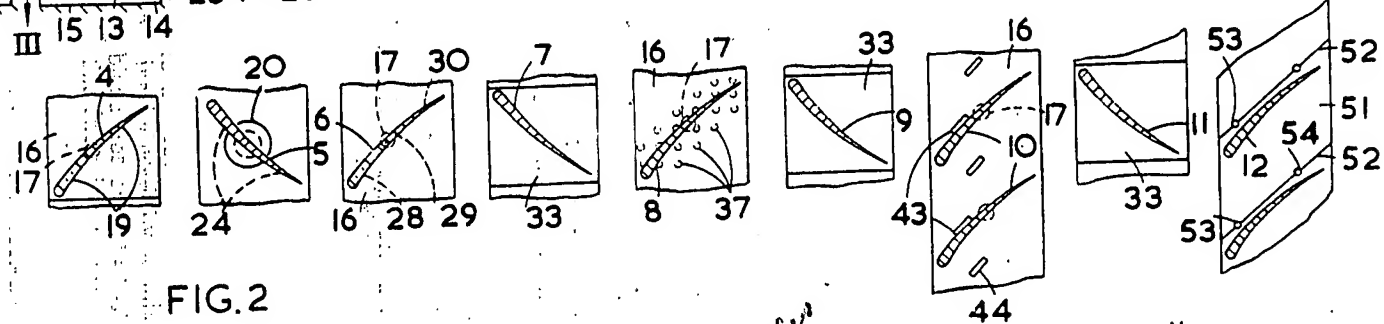

FIG. 2

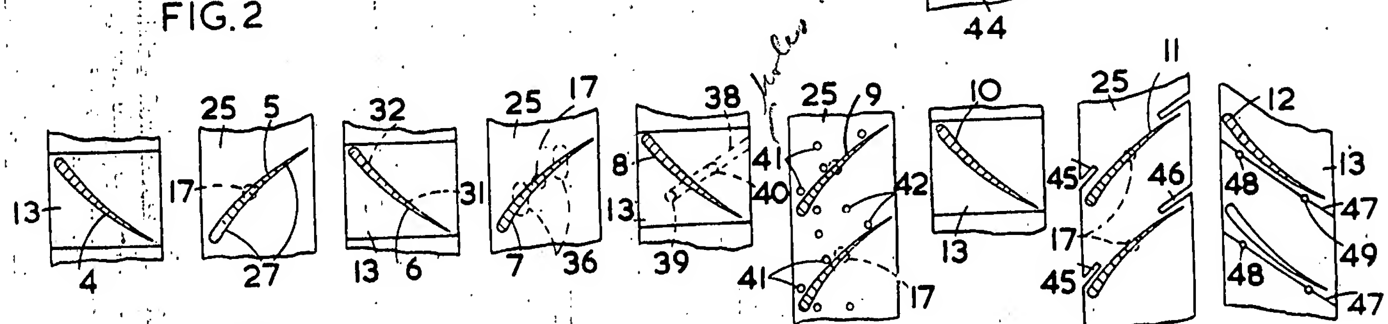

FIG. 3